Determinants of quadic patenting: market access, imitative threat, competition and strength of intellectual property rights

Working Paper Series

#2012-053

Determinants of quadic patenting: Market access, imitative threat, competition and strength of intellectual property rights

Can Huang and Jojo Jacob

Maastricht Economic and social Research institute on Innovation and Technology (UNU-MERIT)
email: info@merit.unu.edu | website: http://www.merit.unu.edu

Maastricht Graduate School of Governance (MGSoG)
email: info-governance@maastrichtuniversity.nl | website: http://mgsog.merit.unu.edu

Keizer Karelplein 19, 6211 TC Maastricht, The Netherlands
Tel: (31) (43) 388 4400, Fax: (31) (43) 388 4499

UNU-MERIT Working Papers

ISSN 1871-9872

Maastricht Economic and social Research Institute on Innovation and Technology, UNU-MERIT

Maastricht Graduate School of Governance MGSoG

UNU-MERIT Working Papers intend to disseminate preliminary results of research carried out at UNU-MERIT and MGSoG to stimulate discussion on the issues raised.

Determinants of Quadic Patenting: Market Access, Imitative Threat, Competition and Strength of Intellectual Property Rights

Can Huang and Jojo Jacob [1]

United Nations University-MERIT and Maastricht University, Keizer Karelplein 19, 6211 TC Maastricht, The Netherlands

Abstract

This paper analyses firms' decisions to seek intellectual property rights in global markets, particularly in China. We advance the notion of quadic patent family, defined as a patent family that consists of patent applications at the European Patent Office, the Japanese Patent Office, the United States Patent and Trademark Office, and the national patent office of a fourth country. We examine the determinants of quadic patenting at the industry level for China, and at the country level for a sample of 38 countries. Our results indicate that quadic patent applications are driven by the need for accessing markets, and for meeting the challenges of imitative threat and product market competition.

Key Words: Quadic patent family, triadic patent family, patent, innovation, imitative threat, Intellectual Property Right, China

JEL Classification: O31, O34

[1] Email address: can.huang@maastrichtuniversity.nl (C. Huang), jacob@merit.unu.edu (J. Jacob).

1. Introduction

In parallel with the growing integration of the world economy, recent years have witnessed increasing internationalization of firms' R&D activities (Patel and Pavitt 1991; Edler, 2004; Belderbos et al., 2008; Nam and Barnett, 2011; Huang et al., 2011). An important development that has accompanied this trend has been the geographical expansion of patent protection beyond the region in which an invention is first patented and where the inventive activity has taken place (OECD, 1994, 2008). While a vast and growing body of literature has analysed the internationalization of R&D activities, only a limited number of studies have explored the factors contributing to the internationalization of patenting activities. Grupp and Schmoch (1999) provide case-study evidence that a firm tends to patent in a foreign country when that country is perceived as the firm's preferred market, even when the invention underlying a patent is made elsewhere. This insight has been confirmed by a handful of econometric studies that have examined the factors shaping patenting by foreigners in a country or a group of countries (Bosworth, 1984; Eaton and Kortum, 1996; Yang and Kuo, 2008). While early studies focused on patenting activities in advanced countries (Bosworth, 1984; Eaton and Kortum, 1996), recent studies have taken a broader perspective, analysing patenting also in emerging economies (Yang and Kuo 2008; Chan 2010; Hu 2010; Ma et al., 2011).

A key weakness of these cross-country studies has been the use of national patents that display considerable variation in quality across countries. These quality differences, which arise from differences in patent laws and conventions across countries, make national patent an imperfect measure for cross-country comparisons (Grupp and Schmoch, 1999). To overcome the shortcomings associated with the simple use of national patent statistics, we advance the notion of quadic patent and examine its determinants in a panel data analyses, first across 19 manufacturing industries in China, and thereafter at the national level across a sample of 38 countries. For every country in our analysis, we define a quadic patent as a patent family that consists of patent applications at the national patent office of that country, the European Patent Office (EPO), the Japanese Patent Office (JPO), and the United States Patent and Trademark

Office (USPTO). Quadic patents represent patents that are of substantive innovative value because patents applied at the tradic patent offices (the EPO, the JPO and the USPTO) have a wide geographic scope, spanning the most advanced and technologically sophisticated regions of the world and hence are known to represent inventions of high value (Harhoff et al., 2003). Therefore the use of quadic patents represents a robust approach to understanding the process of global patenting activities in that it removes the country biases associated with national patents, ensuring comparability of patents applied in a wide array of national patent offices.

As we detail in Section 3, quadic patenting has become very important in many emerging economies, but most significantly in China. Between 1985 and 2005, the proportion of triadic patent families that contained patents filed at the China's State Intellectual Property Office (SIPO) increased from 9 per cent to 61 per cent and continues to grow. Quadic patenting in China represents the most dominant type amongst those in all the non-triadic countries (countries excluding Europe, Japan and the US). In other words, next to the advanced triadic region China is rapidly emerging as an important destination for companies to seek intellectual property rights.

From a theoretical perspective, we argue that quadic patenting in China is in part a capability exploitation strategy aimed at tapping into the vast and growing local market by Multinational Corporations (MNCs) (Dunning, 1995; Hymer, 1976). While knowledge exploitation strategy is well known in the international business literature, it is employed previously mainly in relation to foreign investment decisions by MNCs (Kuemmerle, 1999). We also propose another, complementary explanation of quadic patenting. Growing competition in many industries has induced firms to undertake strategic patenting, for ensuring the patentability of their future inventions by warding off potential competing patents, and for strengthening their positions in strategic negotiations with rivals.

As regards the factors explaining quadic patenting we consider the size of the market, as well as the extent of foreign penetration in the local market, as an important driver of

quadic patenting, in line with the findings of prior studies on international patenting (Bosworth, 1984; Eaton and Kortum, 1996; Yang and Kuo, 2008, Chan, 2010; Hu 2010). While the size of the market signifies the potential for exploiting a firm's knowledge resources, the need for protecting those resources derives from the extent to which local manufacturers are able to imitate a firm's technologies (Chan, 2010; Hu, 2010), and the degree of competition in the local market (Hall and Ziedonis, 2001; Ziedonis, 2004; Noel and Schankerman, 2006; Cockburn and MacGarvie, 2009; Hu 2010). To capture the imitative capability of local manufacturers, we introduce a novel measure, defined as the number of triadic patents of which one or more inventors are located in the host country. This measure represents the technological sophistication of local manufacturing, and therefore is a useful alternative to the conventional measure of technological capability, namely R&D, for which comparable data is either absent or of poor quality, particularly for Chinese manufacturing industries. In addition to technological competition, product market competition too can trigger quadic patenting. Employing data on the sales revenues of firms we derive an index to capture product market competition in China at the two-digit manufacturing level. To the best of our knowledge, ours is the first study that explicitly examines the role of product market competition in shaping international patenting activities. Our analysis at the national level across a sample of non-triadic countries (countries except the members of the EPO, Japan and the US) offers the possibility of testing the importance of an additional variable—the strength of the intellectual property rights (IPR) regime in host countries (Chen and Puttitanun, 2005; Branstetter et al. 2006; Allred and Park, 2007).

In the following section we describe the theory, followed by the hypotheses. Section 3 details the data and discusses the trends in quadic patenting activities. The variables and the econometric model are explained in Section 4. The results of the analyses are discussed in Section 5, and the final section concludes.

2. Theory and Hypotheses

In the literature on international patenting theoretical explanations of foreign patenting

has been noticeably lacking, with the focus mainly being empirical (Yang and Kuo, 2008; Chan, 2010; Hu 2010).[1] In this study, we try to provide theoretical rationales for international patenting by basing our analyses of quadic patenting on the traditional theory of internationalization (Dunning, 1988, 1995; Hymer 1976), and on the resource-based theory of the firm (Wernerfelt, 1984; Peteraf, 1993).

In the former view, MNCs possess certain unique advantages particularly in the form of proprietary technologies which give them an edge over firms in less developed countries. When the technology is standardized and the cost of production becomes cheaper abroad than at home, rather than relegating that task or production and hence transferring the production technology to foreign producers MNCs may prefer to carry out production abroad themselves. Foreign investment by MNCs in cheaper locations abroad thus enables them to *internalize* and *exploit* their *ownership* advantages. While this paradigm of internationalization has been developed in the context of Anglo-American enterprises, it has since been adapted to explain internationalization activities by the so-called emerging MNCs who possess different types of firm-specific ownership advantages than the conventional, technological and marketing advantages enjoyed by their Anglo-American counterparts (Guillen and Garcia-Canal, 2009). We adapt this theory to argue that as firms extend their operations into China and other foreign markets, spurred on by globalization, they also patent their technologies in the host country to ensure the continued exploitation of their technological knowhow. Therefore the theoretical notion of knowledge or capability exploitation appears to be a useful starting point in understanding the causal effects of potential factors on quadic patenting in China and other non-triadic economies.

In addition, we employ the resource-based view for providing theoretical justification for patenting that is strategic in nature, aimed primarily at a firm's future technological development. Given that technological development is cumulative and costly, many firms, particularly those with deep pockets, have developed portfolios of patents so that

[1] An exception is Eaton and Kortum (1995) who view foreign patenting from the perspective of macro economic growth, interpreting it as causing knowledge spillovers in the country where patents are applied for.

their technological development activities are not stifled by patent infringement suits from rival firms (Hall and Ziedonis, 2001; Ziedonis, 2004). Furthermore, such a patent portfolio enables a firm to win favourable terms in cross-licensing negotiations (Hall and Ziedonis, 2001). Strategic patenting therefore can be seen as a mechanism for enhancing a firm's strategic resources, and is therefore distinct from the kind of patenting that is aimed at achieving immediate commercial success in product markets, as discussed in the previous paragraph.

2.1 Hypotheses

Extant literature has emphasized the role of opportunities for knowledge exploitation offered by the host country market in shaping foreign patenting. In this regard, an early study by Bosworth (1984) identified international trade, operations of MNCs, and the size of recipient country's economy as three leading factors influencing international patent flows to and from the UK. These results were underscored by subsequent studies on international patenting. In their analysis of bilateral patenting among the OECD countries Eaton and Kortum (1996) found that the size of a country's market is a major determinant of patenting in that country by foreigners. Yang and Kuo (2008) demonstrated that trade and investment are a major influence on patent applications by residents of a country in another country. Chan (2010) in her study of nine globally leading agricultural biotechnology firms provides further evidence on the importance of the size of the market and trade in shaping international patent application decisions.

From the theoretical lens of knowledge exploitation, while the size of the domestic market represents the potential for knowledge exploitation, foreign investment and import (foreign penetration) may reflect the ease with which such potentials could be exploited by foreign firms. Together they serve to explain the degree to which *market access* is a motive for international patenting. Therefore we make the following prediction:

Hypothesis 1 (market access): *The size of the market and the degree of foreign*

penetration in the local market have a positive influence on quadic patent applications.

International patent applications are typically more costly than domestic ones (Grupp and Schmoch, 1999). Therefore a firm would have a strong motivation to seek intellectual property protection overseas when the risk of its products being imitated, which depends on the technological sophistication of firms in the host country, is substantial. The effect of imitative threat is validated in the study by Hu (2010) who found that technological sophistication of the domestic Chinese industry, captured through the number of domestic patents filed by Chinese applicants, had a significantly positive effect on patenting by foreign firms in China.

In addition to the imitative threat, a highly competitive host-country market also makes the traditional rationale for patenting–that is, for excluding others from making, using, or selling the invention—salient. Competitive market conditions also induce patenting for strategic reasons (Cohen, Nelson and Walsh 2000; Hall and Ziedonis, 2001). Thus in highly competitive industries such as semiconductor, software and electronics, many firms have built large patent portfolios in order to reduce their vulnerability to infringement litigation by their rivals (Ziedonis, 2004; Noel and Schankerman, 2006; Cockburn and MacGarvie, 2009). In these industries, which are characterized by complex technologies with hundreds of patentable elements embodied in one product, no single firm is likely to hold all the rights necessary for a product's commercialization. Possessing a large patent portfolio is vital for cutting through a "thicket" of intellectual property rights to advance technology or legally produce or sell products, and, as already noted, to gain an upper-hand in cross-licensing negotiations and in patent litigations. Few studies have empirically examined the effect of product market competition on international patenting. A partial exception is Hu (2010)'s research which revealed that import competition in China exerts a significantly positive impact on foreign patenting in China, accounting for 36 per cent of annual growth of foreign patenting in China.

In short, when technological competitiveness in an industry or a country is high, firms have a strong reason to patent in order to contain the imitative threat posed by their rivals.

Similarly high product market competition too can trigger patenting for successful commercialization of existing technologies, as well as for fulfilling a firm's key strategic objective of smooth, unhindered technological development. Therefore, we propose the following two related hypotheses:

Hypothesis 2 (imitative threat): *Imitative threat in the local market has a positive influence on quadic patent applications*.

Hypothesis 3 (competitive pressure): *Product market competition has a positive impact on quadic patents applications*.

In addition to the effects of the size of the market, imitative threat, and competition, it is widely recognized that the strength of IPR regime has a major influence on international patenting. In 1995, the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) under the framework of World Trade Organization (WTO) went into effect, which set up minimum standard of global protection of intellectual property rights, including provisions on patent duration (20 years), coverage (invention subject matter), and enforcement mechanisms. Since then many countries have strengthened their intellectual property system (Maskus, 2000). Based on the seminal study by Ginarte and Park (1997), who constructed an index to measure the strength of patent protection in various countries according to the coverage of the patent law, membership in international agreements, loss of protection, and enforcement and duration of protection, scholars have investigated the impact of the strength of patent regimes on innovative activities of firms. In a panel data analysis for 64 developing countries, Chen and Puttitanun (2005) found that the strength of patent regime has a positive impact on innovations, as well as that the strength of patent regime first decreases and then increases with the level of development of the country, forming a U-shaped relationship. Branstetter et al. (2006) showed that IPR reforms over the 1982–1999 period in a sample of 16 countries had a positive effect on technology transfer within the US multinational firms, resulting in an increase in foreign patent applications by these firms. In their pioneering cross-country study, Allred and Park (2007) found an inverted U-shaped

relationship between patent protection and foreign patent filings in developed countries; but no significant relationship was found in the context of developing countries. The inverted U-shaped relation rests on the premise that while firms will have little incentive to incur the costs of filing patent applications in a country where patent law or its enforcement is weak, beyond a certain level of IPR protection further improvements may not be influential in shaping firms' decision to patent. The above discussion leads us to propose the following hypothesis.

Hypothesis 4 (IPR strength): *Strength of IPR has an inverted-U shaped effect on quadic patent applications*.

3. Data

This study consists of two sets of empirical analyses on the determinants of quadic patenting. The first is carried out across 19 two-digit manufacturing industries in China over an 18 year period (1987–2004). The second set of analyses is at the country level across a sample of 38 countries for the 20-year period from 1985 to 2004. For the two sets of analyses we build two unique data sets, combining data on patents, production and trade respectively for the Chinese manufacturing industries and for our sample of 38 countries.

The patent data used in the study are drawn from the PATSTAT database which is derived from the EPO's "master documentation database (DOCDB)" and contains bibliographic data, citations and patent family links from more than 100 patent offices worldwide (European Patent Office, 2011). In this paper we adopt the DOCDB patent family definition, which refers to patent applications that claim exactly the same prior applications as priorities (these can be Paris Convention priorities or just technical relation priorities) (Picci, 2010). To each family we assigned a single application year, defined as the earliest year of application in that family. This resolves a key weakness of lack of timeliness in national patents in which the year of application of a given patent may not necessarily correspond to the year of invention due to strategic or administrative delays in the application (Baudry and Dumont, 2006). Inventions whose protection is

sought in multiple countries tend to have higher quality (Lanjouw and Schankerman, 2004) because obtaining and maintaining patents in multiple countries is costly (Hall and Helmers, 2010). In this regard triadic patents—families of patents which contain patents applied at the EPO, the JPO and the USPTO—are emerging as a particularly attractive measure for international comparison of patent activities (Baudry and Dumont 2006; Picci, 2010). One key weakness of using national patents in cross-country studies is that national patents differ widely in quality because of differences across countries in patent laws and conventions. Japanese patent law for example requires that multiple claims, which can be filed as one patent application at the EPO or the USPTO, should be filed as separate applications (Grupp and Schmoch, 1999). Triadic patents overcome this weakness as they refer to patents whose geographic scope span three of the world's most technologically and economically advanced regions, and therefore represent inventions of substantial value (Harhoff et al., 2003).

Building on the idea of triadic patents, we define a quadic patent for a given country as a patent family that on the one hand consists of patent applications at the national patent office of that country, and on the other fulfils the conditions of a triadic patent family (that is, a family consisting of patent applications at the EPO, the JPO, and the USPTO). In deriving industry level triadic and quadic patents for Chinese manufacturing industries we calculate the fractional counts of patents in four-digit technology classes (International Patent Classification, or IPC, classes) and map them into two-digit manufacturing industries (International Standard Industrial Classification) using the OECD Technology Concordance (Johnson, 2002). [2]

For the cross-country study we selected 38 countries from over 100 countries covered in the PATSTAT database based on the criteria that they had received at least one quadic

[2] The sectoral classification in the OECD Technology Concordance follows the International Standard Industrial Classification (ISIC, Rev. 3), while the classification of manufacturing sectors for one of the key explanatory variables, imports to Chinese manufacturing industries, which is taken from the World Bank's Trade, Production and Protection (1976–2004) Database, follows ISIC (Rev. 2). The classification for the other explanatory variables derived from Chinese statistical yearbooks follows the Chinese industry sector classification GB/T 4754-2002. We harmonize these three different classification systems to obtain consistent data for the 19 manufacturing sectors (for details of the harmonization, see Table A in Appendix).

patent application (that is an application that belonged to the triadic patent family) during the observation period. The member states of the EPO, Japan and the US are excluded from this analysis. The countries analysed are predominantly emerging or developing economies, with a few exceptions, like Australia, Canada and New Zealand. [3]

For production and trade data for the industry-level study on China, we use two sources. One is *China Statistical Yearbook* from which we derive the data on total sales revenue of the general manufacturing firms in China and that of foreign-owned manufacturing firms. The former data is available for the period 1987–2004, and the latter for 1993–2004. The second key source of Chinese data is the *Annual Survey of Industrial Enterprises* database of the National Bureau of Statistics of China from which we obtained data on the sales revenue of all state-owned and non-state-owned manufacturing firms with revenues of more than five million RMB during the period 1999–2004. [4] For data on imports at the level of both two-digit Chinese manufacturing industries and the manufacturing industries of the 38 countries we use the World Bank's Trade, Production and Protection Database. For data on manufacturing value added for the cross-country study we use the World Bank's World Development Indicators database. Finally, we employ the Ginart and Park index (Ginart and Park, 1997; Park, 2008) for measuring the strength of IPR protection at the national level.

3.1 Trends in triadic and quadic patenting

Figure 1 shows the trend in triadic patenting over the period 1985-2005, and the share of quadic patents in triadic patents for a selected group of countries: in descending order, Canada, China, Australia, South Korea and Brazil, as well as three BRICS countries—Russia, India and South Africa. Since the early 1990s the number of triadic patents has

[3] The countries (regions) covered in this study include Argentina, Australia, Brazil, Canada, Chile, China, Colombia, Costa Rica, Algeria, Ecuador, Egypt, Guatemala, Hong Kong, Honduras, Indonesia, Israel, India, Kenya, South Korea, Sri Lanka, Morocco, Malawi, Mexico, Malaysia, New Zealand, Panama, Peru, Philippines, Russia, Singapore, El Salvador, Taiwan, Tunisia, Trinidad and Tobago, Ukraine, Uruguay, Vietnam, South Arica.

[4] There are 146,251, 147,413, 155,935, 165,988, 179,749 and 255,266 manufacturing firms in the dataset for the years 1999, 2000, 2001, 2002, 2003 and 2004, respectively. Prior studies that used this dataset include Hsieh and Klenow (2009) and Zhang et al. (2010).

been growing rapidly, reaching over 60,000 in 2005 starting from about 18,000 in 1985. Among the group of countries, while Canada and Australia were countries traditionally with the highest share of quadic patents, during recent years their shares have been declining with a rapid growth in quadic patenting activities in China and more recently in South Korea. Between 1985 and 2005, the proportion of triadic patent families that contained patents filed in China increased from 9 per cent to 61 per cent, while that in South Korea increased much more slowly, from 13 per cent to 42 per cent. This proportion has been much lower and has remained surprisingly stagnant over the years in the BRICS countries other than China—Brazil, South Africa, Russia and India. This suggests the existence of a dominant type of quadic patent family consisting of patents applied in Europe, Japan, the US and China for the same inventions. In other words, in addition to Europe, Japan and the US, China has rapidly emerged as an important location in which companies seek to protect their intellectual property rights. This finding confirms Nam and Barnett (2011)'s study that China has moved up in the ranking in terms of degree centrality in global network of patents from 1996 to 2005.

(Figure 1 here)

An important question in respect to the rise of quadic patenting is to what extent local inventors are associated with quadic patents. For the eight countries discussed above, the involvement of local inventors in quadic patenting is meagre for all except South Korea. The share of South Korean inventors in total inventors increased from five per cent in 1993 to 30 per cent in 1997, before declining and stabilizing at around 10–15 per cent in the 2000s. For the other top quadic patenting countries such as Canada, China, Australia, and Brazil, the share was never more than five per cent. This underscores a key premise of our study that quadic patenting represents an international patent application decision by firms.

(Figure 2 here)

Finally, Figure 3 shows the proportion of quadic patents involving China in triadic

patents across the 19 manufacturing industries during the period 1985–2005. The sectoral patterns mirror the overall trend in quadic patenting in China with a rather steep increase in the proportion of quadic patenting across all sectors since the early 1990s and a tapering off of that trend in the most recent years. The degree of quadic patenting does however exhibit substantial heterogeneity across industries with the highest proportion of quadic patenting being in tobacco while the lowest being in rubber and plastic products, and transport equipment.

(Figure 3 here)

4. Variables and Econometric Methods

The first set of our empirical analyses, which we label the China regression, examines the determinants of quadic patenting in 19 Chinese two-digit manufacturing industries over a period of 18 years from 1987 to 2004 . The second set of analyses, which is labelled the cross-country regression, is at the country level, examining the factors contributing to quadic patenting for a sample of 38 countries for the period of 1985–2004. The dependent variables in the two analyses are the number of quadic patent applications respectively in the 19 Chinese manufacturing industries and in the 38 countries.

4.1 Independent variables

To test the first hypothesis that the number of quadic patents is positively correlated with the size of the market and the degree of foreign penetration in the host economy, we use three variables. The first two variables are used in both the China and cross-country regressions, while the last variable is used only in the China regression. The first variable is the total sales revenue of each of the 19 manufacturing industries in China for the China regression and the manufacturing value added of each country for the cross-country regression. This variable represents the size of the market that foreign firms can tap into. The next variable is the volume of China's imports at the two-digit manufacturing sector level for the China regression, and the volume of manufacturing

imports into each country for the cross-country regression. This variable captures the importance respectively of Chinese industries and countries as export markets for foreign firms. The third variable, which is limited to the China regression, is the sales revenue of the foreign-owned manufacturing firms in China, measuring the importance of China as a market for foreign-owned firms operating in China. We were unable to construct a similar variable at the country level because of the absence of consistent data on sales revenue of foreign-owned manufacturing firms in the 38 countries. Our variables representing foreign penetration in the local market (sectoral and manufacturing imports and sales of foreign-owned manufacturing firms) are an improvement over the aggregate measures, like total imports and total foreign direct investment (FDI) into a country, used in previous studies (Bosworth, 1984; Eaton and Kortum, 1996; Yang and Kuo, 2008). The latter measure (total FDI) is particularly weak because while more than 95 per cent of the patents belong to the manufacturing industries (own estimations using PATSTAT) in 19 countries for which some data on FDI in manufacturing industries are available (from the United Nations Conference on Trade and Development), the share of manufacturing FDI in total FDI is much lower, varying in a wide range from 5 to 60 per cent.

To test the second hypothesis that the imitative threat in the host market has a positive effect on quadic patenting, we use the number of triadic patents originating in a Chinese manufacturing industry or a country as a proxy for the technological capability of the industry or the country. We define triadic patents originating in a Chinese manufacturing industry or a country as those triadic patents with at least one inventor being a resident in China or in the country. We use triadic patents instead of national patents (as for example in Hu, 2010) in order to avoid country biases, noted earlier, associated with the latter type of patents. A relatively large number of triadic patents originating in an industry or a country indicate that the industry (the country) poses significant threat in terms of its imitative capabilities.

The third hypothesis, which relates product market competition to quadic patenting, is empirically tested only in the China regression. For this we measure at the two-digit level

the Herfindahl index of concentration of sales revenue of all state- and non-state-owned manufacturing firms (including foreign-owned firms) with sales revenue of more than five million RMB in China during the period of 1999–2004. The average Herfindahl index of the 19 two-digit manufacturing sectors dropped from 0.0054 in 1999 by 22 per cent to 0.0042 in 2005, indicating stiffening of competition in the Chinese manufacturing industry during this period. Our use of firm level data for measuring the degree of competition represents an improvement compared to the approach adopted in previous related studies. Hu (2010) for example constructed a measure of import competition between foreign countries in the Chinese market. A key weakness of this measure is that it does not capture the competitive threat posed by domestic firms, as well as that by foreign firms operating in the host country. The latter is particularly relevant given the fact that many leading multinational companies have established manufacturing bases in China.

In order to test our fourth hypothesis on the relationship between the strength of IPR and quadic patenting we use the Ginart and Park index (GP index) (Ginart and Park, 1997; Park, 2008) which measures the strength of patent protection in various countries. The GP index is available only every five years (for example we have GP_t for year t and GP_{t+5} for year t+5), while the rest of our data and our analysis are on an annual basis. We try two ways to annualize the GP index. The first approach to calculate GP index for the intervening years is $GP_{t+n} = GP_t + \frac{n(GP_{t+5} - GP_t)}{5} (1 \leq n \leq 4)$ and the second approach is $GP_{t+n} = GP_t (1 \leq n \leq 4)$. The results based on the two approaches are not materially different and we report the results based on the first approach.

4.2 Control variables

In addition to the key explanatory variables defined above, we include in the regression models a number of control variables. Since the mid 1990s, member states of the WTO were required to provide a minimum level of patent protection under the TRIPS. To capture the intellectual property protection afforded under WTO, we include in the cross-country regression the *WTO dummy* variable whose value is one if a country is a WTO

member and zero otherwise.

To control for the possible inventive involvement of the host country in quadic patents, in the China and cross-country regressions we include the *share of inventors* from respectively China and the host country in total inventors of quadic patents. As noted before, however, most of the quadic patents in China and in majority of the countries, with the exception of South Korea, had very little host-country invention links. In the China regression we employ the *number of triadic patents* filed per manufacturing industries. This is to control for differences in global patenting patterns which may stem for example from fluctuations in the pace of technological change, across industries and over time. All our regression models include *year dummies* to control for factors which vary over time, but unaccounted for by the explanatory and control variables. All the variables and their definition are summarized in Table 1.

(Table 1 here)

4.3 Method

The empirical models in our study examine the factors contributing to quadic patenting respectively across Chinese manufacturing industries and across a sample of 38 countries. Our dependent variables are count variables with non-negative integer values which suggest that either the Negative Binomial Model or the Poisson Model is preferable over linear regression models because the former models explicitly take into account the non-negativity and discreteness of the dependent variable. However, the Poisson estimator's efficiency relies on the assumption that the conditional mean is equal to the conditional variance (equidispersion), which is often violated in practice. Our dependent variables display considerable dispersion, and a likelihood ratio test confirmed the violation of the assumption of equidispersion. With the over-dispersion of our data, the Poisson estimator would result in underestimated standard errors and, accordingly, inflated statistical significance. We employ the Negative Binomial model in this study because it does not depend on the equidispersion assumption and thus is more flexible than the Poisson

model. As regards the choice between the fixed- versus random-effects models, the latter assumes that the random-effects (individual specific unobservables) are uncorrelated with the regressors (individual specific observables). If the assumption is violated, the random-effects model yields inconsistent estimates. Using the Hausman test we were able to reject this assumption and favour fixed-effects models in five of the six specifications in the analysis on the Chinese manufacturing industries. However, we were not able to reject the random-effects model in the cross-country analysis. Therefore in addition to the results of the fixed-effects models we report those of random-effects models whenever they were not rejected. The results of the rejected random-effects models are however reported in Table B in Appendix.

5. Results

Table 2 presents the summary statistics and correlation matrix of the variables. The number of quadic patents in an average Chinese manufacturing industry is about 650 and that in an average country in the sample is 2000, and both variables demonstrate a high level of dispersion. The number of triadic patents originating in China is about four (the natural logarithm value is 1.4), while the share of inventors who reside in China is only about 0.2% (the natural logarithm value is -6.3). The small value for the average Herfindahl index points to the presence of a competitive market environment in Chinese industries. Turning to the summary statistics for the cross-country sample, the share of inventors who reside in the country is quite low (below 0.003%, the natural logarithm value is -10.5) while the number of triadic patents originating in the country is on average about 11 (the natural logarithm value is 2.4). The correlation matrices of variables in the two sets of studies point to moderate levels of correlations with a few exceptions. In both the China and cross-country regressions, the variables sales and imports display a relatively high level of correlation. Additionally in the China regression, the variable sales revenue of foreign-owned firms also shows high correlations with total sales and imports. Because these three variables are highly correlated (see Table 2), we add them separately to the model to avoid multicollinearity problem.

(Table 2 here)

The results of the factors driving quadic patenting in the Chinese manufacturing industries and in the 38 countries are reported in Table 3 and Table 4 respectively. The China regression models are estimated for three different time periods because not all key explanatory variables are available for the same period. The Herfindahl index could be constructed only for the 1999-2004 period, while information on sales revenue of foreign-owned firms in China are available only since 1993.

In support of hypothesis 1, the coefficients of these three variables are positive and statistically significant in six of the seven specifications of the China regression (Table 3), indicating that foreign firms applied for more quadic patents in order to access the growing Chinese market; the only model (Column 5, Table 3) in which imports is not significant at the 10 per cent level is for the sample with the shortest time span, 1999-2004. In the cross-country regression, while the coefficients of manufacturing value added are statistically significant, those of manufacturing imports are not (Table 4). The latter may be the result of imports as an imperfect measure of market access for foreign firms, due to barriers to trade. In addition to exports, foreign firms may use other mechanisms, such as FDI, to cater host countries' markets.

(Table 3 here)
(Table 4 here)

Hypothesis 2 on the effect of imitative threat is well supported by the statistically significant coefficient of triadic patents originating in China in all but one specification in which the sample duration is the shortest (column 5, Table 3). In the cross-country regression, the coefficient of this variable has the expected positive sign and is statistically significant in all specifications (Table 4). We find a statistically significantly negative coefficient for the Herfindahl index in all specifications in Table 3. This confirms our hypothesis 3, suggesting that industries experiencing fiercer competition have attracted more quadic patents.

In line with the prediction of hypothesis 4, we find positive and significant coefficients of the variable strength of patent regime, indicating that strengthening of patent protection regime can result in increase in quadic patent filings (Table 4). This confirms the findings in the extant literature on the positive effect of a strong IPR regime on patenting.

As regards the results on the control variables, the coefficient of the WTO membership has no statistically significant effect on quadic patenting. The coefficients of the share of inventors residing in China are never positive, underscoring the foreign origin of triadic patents in China (Table 3). In the cross-country regression the coefficients of the corresponding variable share of inventors residing in the country are not significant. Some of the coefficients of the control variable triadic patents in the China regression are statistically significant, but some are not. The year dummies are all positive and significant (not reported due to limited space, but are available upon request from the authors). In the China regression the coefficients of the recent year dummies are greater than those of the early ones, indicating an intensification of quadic patenting activities in China in recent years.

6. Conclusions

In conjunction with the growing economic globalization in the world economy, inventions created in one part of the world are increasingly being patented in other regions of the world. While a few studies have explored the factors driving the internationalization of patenting, a key weakness of these studies has been the use of national patents which differ in quality across countries. In this paper we advanced the notion of quadic patent, and examined the determinants of quadic patenting at the sectoral level in China, as well as at the country level for a sample of 38 countries. Quadic patents are defined specific to each country as referring to patent families from which patent applications are filed at the national patent office and at the triadic patent offices (the EPO, the JPO and the USPTO). As all quadic patents share the common characteristic that their geographic scope spans three of the world's most technologically and

economically advanced regions (Europe, Japan and the US) they represent patents of comparable quality.

While in the past quadic patenting was important in the context of developed countries like Canada and Australia, recent years have witnessed a significant rise in quadic patenting activities in emerging economies, most notably in China. The share of triadic patents which were also sought protection in China has risen to over 60 per cent in recent years. Nearly all of the quadic patenting activity in China originates abroad, and therefore our empirical analyses can be compared with the extant literature on foreign patenting in China. Bringing together data on production, trade and patents we examined the factors shaping quadic patenting at the level of two-digit Chinese manufacturing industries. In an extension we also examined the determinants of quadic patenting at the country level for a sample of 38 countries.

Our analyses confirmed that quadic patenting in China owed significantly to the knowledge-exploitation potentials offered by the vast Chinese market (*market access*). In addition to the absolute size of the domestic manufacturing industries, the extent to which foreign firms have penetrated into the Chinese market through local production and sale in China and through imports has been an important influence on quadic patenting. We further showed that imitative threat posed by the Chinese manufacturing industries has also spurred quadic patenting. Finally, the intense competition in the Chinese markets has been another important factor causing quadic patenting activity there. A similar analysis at the country level on a sample of 38 non-traidic countries confirmed the broad findings on the importance of market size and the imitative threat posed by host-country firms. In addition, the cross-country study also highlighted the importance of the strength of IPR as a positive factor in shaping quadic patenting.

As regards the empirical contributions of the study, we highlighted the need for recognizing quadic patents as an important measure in analysing international patenting activities, especially in relation to emerging economies such as China. In addition, we introduced a novel measure of innovative capability, namely triadic patents originating in

a country, defined as the count of triadic patents of which one or more inventors reside in that country. Owing to the availability of patent data with rich information on the location of inventive activities, this measure is easy to construct, and is of comparable quality across countries. Therefore this indicator is a useful alternative to R&D for which consistent data is missing for many countries, especially for China at the sectoral level. Finally, to the best of our knowledge this is the first study that explicitly takes into account, and finds evidence for, the contribution of domestic market competition in driving international patenting.

This paper also makes important contributions to the theoretical literature. Prior studies on international patenting adopted a largely empirical perspective. In this paper we related quadic patenting to the notion of knowledge exploitation, originally employed in the literature on foreign investment, as well as on the resource-based view of the firm. We argued that three key factors driving quadic patenting—market access motive, imitative threat, and competitive pressure—point to a knowledge exploitation strategy by firms. Furthermore, we related the significance of product market competition also to the resource-based view of the firm, suggesting that it may partly reflect the strategic motives for patenting—patenting aimed at facilitating future technological progress, and not necessarily at immediate exploitation of existing know how. However, a more nuanced understanding of the motives underlying quadic patenting would require analyses at the firm level. We leave that for future research.

References:

Allred, B. B. and W. G. Park, 2007. The influence of patent protection on firm innovation investment in manufacturing industries. Journal of International Management, 13, 2, 91-109.

Bacchiocchi, E. and Montobbio, F., 2010. International Knowledge Diffusion and Home-bias Effect: Do USPTO and EPO Patent Citations Tell the Same Story? The Scandinavian Journal of Economics, 112(3): 441–470.

Baudry, M. and Dumont, B., 2006. Comparing firms' triadic patent applications across countries: Is there a gap in terms of R&D effort or a gap in terms of performances? Research Policy, 35: 324–342.

Belderbos, R., E. Lykogianni and R. Veugelers. 2008. Strategic R&D location in European manufacturing industries. Review of World Economics, 14, no. 2: 1-24.

Branstetter, L. G., R. Fisman, et al., 2006. Do stronger intellectual property rights increase international technology transfer? Empirical evidence from US firm-level panel data. Quarterly Journal of Economics, 121, 1, 321-349.

Bosworth, D. L., 1984. Foreign patent flows to and from the United Kingdom. Research Policy, 13, 2, 115-124.

Chan, H. P., 2010. The Determinants of International Patenting for Nine Agricultural Biotechnology Firms. Journal of Industrial Economics, 58, 2, 247-278.

Chen, Y.M. and Puttitanun, T., 2005. Intellectual Property Rights and Innovation in Developing Countries, Journal of Development Economics, 78, 474-493.

Cockburn, I and MacGarvie, M., 2009. Patents, Thickets and the Financing of Early-Stage Firms: Evidence from the Software Industry, Journal of Economics & Management Strategy, 18, 729-773.

Cohen, W. M., Nelson, R. R. and Walsh, J. P., 2000. Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not), NBER working paper 7552.

Dunning, John H., 1988. The eclectic paradigm of international production: a restatement and some possible extensions. Journal of International Business Studies 19 (1), 1–31.

Dunning, J.H. 1995. Reappraising the eclectic paradigm in an age of alliance capitalism. Journal of International Business Studies, 26: 461-91.

Eaton, J. and S. Kortum, 1996. Trade in ideas - Patenting and productivity in the OECD. Journal of International Economics, 40, 3-4, 251-278.

Edler, J. 2004. International research strategies of multinational corporations: A German perspective. Technological Forecasting and Social Change, 71, 599-621.

European Patent Office, 2011. PATSTAT Database, October 2011 edition.

Ginarte, J. C. and W. G. Park, 1997. Determinants of patent rights: A cross-national study. Research Policy, 26, 3, 283-301.

Grupp, H. & Schmoch, U., 1999. Patent statistics in the age of globalisation: new legal procedures, new analytical methods, new economic interpretation. Research Policy 28: 377–396

Guillen, M.F., Garcia-Canal, E., 2009. The American model of the multinational firm and the 'new' multinationals from emerging economies. Academy of Management Perspectives 23(2), 23–35.

Hall, B. H. and R. H. Ziedonis, 2001. The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979-1995. The RAND Journal of Economics, 32, 1, 101-128.
Harhoff, D., Scherer, F.M. and Vopel, K. (2003), Citations, family size, opposition and the value of patent rights. Research Policy 32: 1343–1363.
Hu, A.G., 2010. Propensity to patent, competition and China's foreign patenting surge, Research Policy, 39, pp. 985–993.
Huang, H.-C., Shih, H.-Y. and Wu, Y.-C. Contagion effects of national innovative capacity: Comparing structural equivalence and cohesion models. Technological Forecasting and Social Change, 78, 244-255.
Hsieh, C. T. and Klenow, P. J. 2009. Misallocation and Manufacturing TFP in China and India. Quarterly Journal of Economics, 124:4, pp. 1403-48.
Hymer, Stephen H. 1976. The international operations of multinational firms: A study of foreign direct investment. Boston, MA: MIT Press.
Johnson, D. K., 2002. The OECD Technology Concordance (Otc): Patents by Industry of Manufacture and Sector of Use, OECD Science, Technology and Industry Working Papers, 2002/5, OECD Publishing.
Kuemmerle, W., 1999. The drivers of foreign direct investment into research and development: An empirical investigation. Journal of International Business Studies 30: 1–24.
Lanjouw, J. O., Schankerman, M., 2004. Patent quality and research productivity: measuring innovation with multiple indicators. Economic Journal 114 (495), 441-465.
Ma, Z., Lee, Y. and Chen, C.-F. P. 2009. Booming or emerging? China's technological capability and international collaboration in patent activities. Technological Forecasting and Social Change, 76, 787-796.
Maskus, Keith, 2000. Intellectual Property Rights in the Global Economy, Institute of International Economics: Washington D.C.
Nam, Y. and Barnett, G. A., 2011. Globalization of technology: Network analysis of global patents and trademarks. Technological Forecasting and Social Change, 78, 1471-1485.
Noel, M. and Schankerman, M., 2006, Strategic Patenting and Software Innovation, CEPR Working Paper 5701.
OECD, 1994. The Measurement of Scientific and Technological Activities: Using Patent Data as Science and Technology Indicators. Patent Manual 1994, OECD / GD 94 114, Paris.
OECD, 2008. Compendium of Patent Statistics, OECD, Paris.
Park, W. G., 2008. International patent protection: 1960-2005. Research Policy, 37, 4, 761-766.
Patel, P. and K. Pavitt, 1991. Large firms in the production of the world's technology: an important case of non-globalisation. Journal of International Business, 22, no. 1: 1-21.
Peteraf, M., 1993, The Cornerstones of Competitive Advantage: A Resource-based View, Strategic Management Journal, 14, 171-191.
Picci, L., 2010 The internationalization of inventive activity: A gravity model using patent data, Research Policy, 39, pp. 1070–1081.

Wernerfelt, B., 1984, A Resource-based View of the Firm, Strategic Management Journal, 5, 171-180.

Yang, C.-H. and N.-F. Kuo, 2008. Trade-related influences, foreign intellectual property rights and outbound international patenting. Research Policy, 37, 3, 446-459.

Zhang, Y., H. Y. Li, Y. Li, and L. A. Zhou. 2010. FDI Spillovers in an Emerging Market: the Role of Foreign Firms' Country Origin Diversity and Domestic Firms' Absorptive Capacity. Strategic Management Journal, 31:9, pp. 969-89.

Ziedonis, R. H., 2004. Don't Fence Me In: Fragmented Markets for Technology and the Patent Acquisition Strategies of Firms. Management Science, 50, 6, 804-820.

Table 1: Definition of Variables

Variable name	Definition and note
China regression (unit of analysis: Chinese manufacturing industries)	
Quadic patents	Number of quadic patent family (A patent family consists of patents applied for in Europe, Japan, the US and China.)
Total sales revenue	Logarithm of sales revenue (unit: 100 million RMB, 1990 constant price)
Imports	Logarithm of volume of China's imports (unit: thousand US dollars)
Sales revenue of foreign-owned firms	Logarithm of sales revenue of foreign-owned firms (unit: 100 million RMB, 1990 constant price)
Triadic patents originating in China	Logarithm of number of the triadic patents (patents applied for in Europe, Japan and the US) whose (at least one) inventors reside in China
Herfindahl index	Logarithm of $\sum_{i=1}^{n}(\text{market share of i firm in the two} - \text{digit manufacturing sector})^2$
Share of inventors who resides in China	Logarithm of the number of inventors of quadic patents residing in China divided by the number of total inventors
Triadic patents	Logarithm of number of triadic patents
Year dummy variables	The base groups for the regressions (1)-(2b), regression (3) and regressions (4)-(6) are 1987, 1993 and 1999.
Cross-country regression (unit of analysis: 38 countries or regions)	
Quadic patents	Number of quadic patent family (A patent family consists of patents applied for in Europe, Japan, the US and China.)
Manufacturing value added	Logarithm of value added of the respective country's manufacturing industries (unit: US dollar)
Manufacturing imports	Logarithm of volume of the respective country's imports of manufacturing industries (unit: thousand US dollars)
Triadic patents originating in the country	Logarithm of number of the triadic patents whose (at least one) inventors reside in the respective country
Strength of patent regime	An index constructed by Ginarte and Park (1997) and Park (2008) to measure the strength of patent protection in 110 countries. The index ranges in value from zero to five. Higher value of the index indicates stronger protection.
(Strength of patent regime)^2	Square of index of strength of patent regime
WTO membership	The value is 1 if the country is a member of WTO in that year, otherwise 0.
Share of inventors who reside in the country	Logarithm of the number of inventors of quadic patents residing in the respective country divided by the number of total inventors
Year dummy variables	The base group is 1985.

Table 2: Correlation Matrix

	China regression	Mean	Standard deviation	1	2	3	4	5	6	7	8
1	Quadic patents	654.0	1471.0	1							
2	Total sales revenue	6.9	1.1	.35	1						
3	Imports	14.7	1.7	.57	.65	1					
4	Sales revenue of foreign-owned firms	5.6	1.5	.35	.65	.83	1				
5	Triadic patents originating in China	1.4	1.5	.85	.41	.64	.52	1			
6	Herfindahl index	-6.1	1.2	-.20	-.08	-.19	-.46	-.26	1		
7	Share of inventors who reside in China	-6.3	1.3	.41	.25	.22	.27	.47	-.13	1	
8	Triadic patents	6.0	1.9	.78	.38	.68	.56	.94	-.24	.25	1
	Cross-country regression	Mean	Standard deviation	1	2	3	4	5	6	7	8
1	Quadic patents	1999.7	4881.3	1							
2	Manufacturing value added	22.9	1.8	.56	1						
3	Manufacturing imports	16.1	1.6	.57	.88	1					
4	Triadic patents originating in the country	2.4	2.0	.70	.78	.83	1				
5	Strength of patent regime	2.7	1.1	.42	.35	.54	.60	1			
6	(Strength of patent regime)^2	8.3	5.4	.47	.39	.56	.64	.98	1		
7	WTO membership	0.8	0.4	.08	.18	.19	.20	.29	.28	1	
8	Share of inventors who reside in the country	-10.5	4.6	.57	.61	.61	.76	.49	.53	.13	1

Table 3: Determinants of Quadic Patent Family: China Regression

Independent variables	Dependent variable: Quadic patents						
	1987–2004	1987–2004	1987–2004	1993–2004	1999–2004	1999–2004	1999–2004
	Fixed-effects	Fixed-effects	Random-effects	Fixed-effects	Fixed-effects	Fixed-effects	Fixed-effects
	(1)	(2a)	(2b)	(3)	(4)	(5)	(6)
Total sales revenue	.28***	-	-	-	.44***	-	-
	(.051)				(.068)		
Imports	-	.064**	.075***	-	-	.044	-
		(.027)	(.026)			(.060)	
Sales revenue of foreign-owned firms	-	-	-	.10**	-	-	.33***
				(.050)			(.053)
Triadic patents originating in China	.097***	.11***	.10***	.093***	.10**	.072	.10**
	(.023)	(.025)	(.024)	(.033)	(.048)	(.055)	(.050)
Herfindahl index	-	-	-	-	-.14***	-.11*	-.13***
					(.046)	(.059)	(.044)
Share of inventors who reside in China	-.047***	-.034**	-.031**	-.019	-.050	-.065*	-.037
	(.015)	(.015)	(.015)	(.019)	(.033)	(.033)	(.032)
Triadic patents	.17**	.089	.31***	.052	.13	-.13	.29**
	(.081)	(.082)	(.10)	(.11)	(.13)	(.16)	(.13)
Constant	-.17	1.13*	-.41	2.73***	-.65	4.17***	-.29
	(.63)	(.66)	(.75)	(.79)	(.87)	(1.43)	(.84)
Year dummy	Included	Included	Included	Included	Included	Included	Included
Number of observations	342	342	342	228	114	114	114
Number of group	19	19	19	19	19	19	19
Log Likelihood	-1301.1	-1310.6	-1491.5	-913.8	-419.6	-420.7	-421.0
Chi-square statistic of the Hausman test	105.1***		-9.8	253.4***	6.0***	58.7***	62.4***

Note: The data between the parentheses are standard deviations. *** denotes significance at the 1% level, ** denotes significance at the 5% level, * denotes significance at the 10% level.

Table 4: Determinants of Quadic Patent Family: Cross-Country Regression

Independent variables	Dependent variable: Quadic patents			
	1985–2004			
	Fixed-effects	Random-effects	Fixed-effects	Random-effects
	(1a)	(1b)	(2a)	(2b)
Manufacturing value added	.10*	.13**	-	-
	(.064)	(.064)		
Manufacturing imports	-	-	.084	.099
			(.064)	(.064)
Triadic patents originating in the country	.29***	.28***	.32***	.33***
	(.057)	(.057)	(.052)	(.051)
Strength of patent regime	.54***	.53***	.51***	.49***
	(.19)	(.19)	(.18)	(.18)
(Strength of patent regime)^2	-.0029	.0018	.0019	.0061
	(.035)	(.034)	(.033)	(.033)
WTO membership	.16	.11	.10	.085
	(.15)	(.15)	(.13)	(.13)
Share of inventors who reside in the country	.013	.012	.015	.015
	(.014)	(.014)	(.012)	(.012)
Constant	-4.39***	-5.07***	-3.23***	-3.43***
	(1.41)	(1.43)	(.94)	(.94)
Year dummy	Included	Included	Included	Included
Number of observations	675		706	
Number of groups	36 [2]		38	
Log Likelihood	-3153.1	-3515.3	-3543.7	-3933.7
Chi-square statistic of the Hausman test	-11.8		-69.2	

Note:
1.The data between the parentheses are standard deviations. *** denotes significance at the 1% level, ** denotes significance at the 5% level, * denotes significance at the 10% level.
2. The data of value added of manufacturing industries are not available for Israel and Taiwan. So these two countries (regions) are not included in this regression.

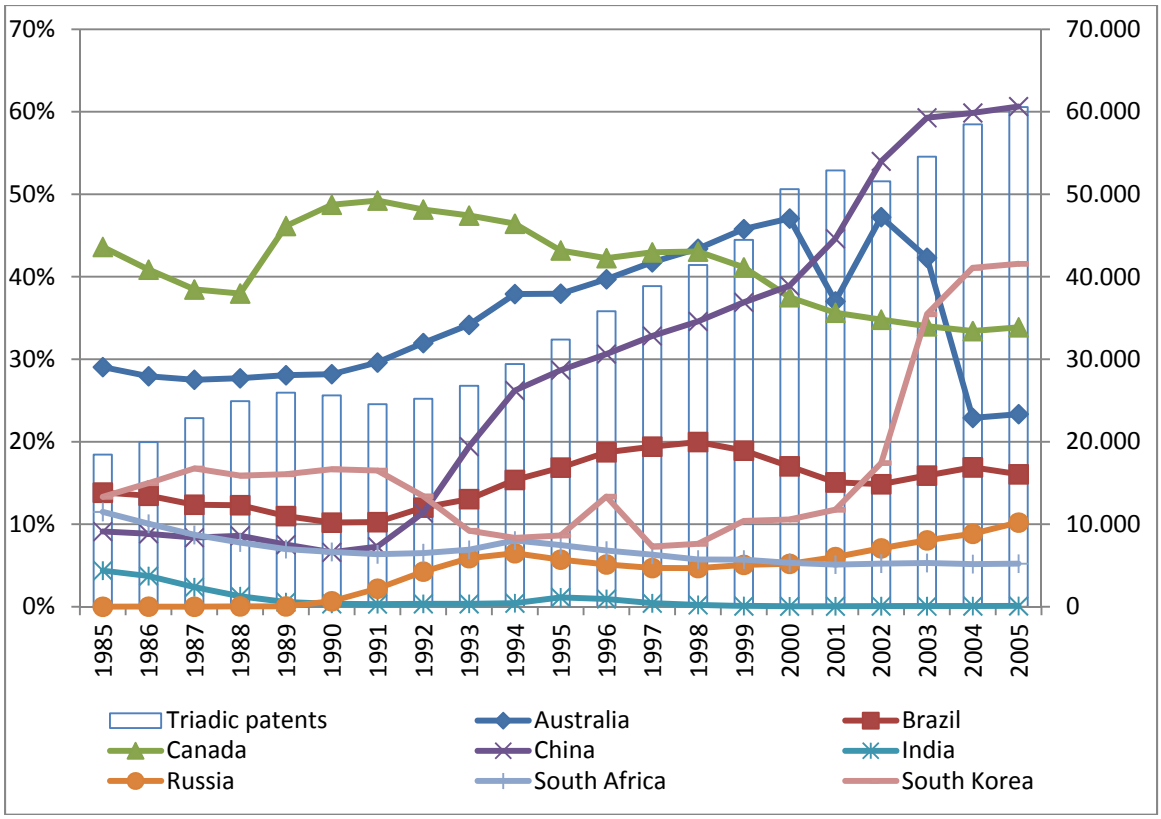

Figure 1: Trends in Triadic Patents and the Proportion of Quadic Patents of Eight Countries to Triadic Patents: 1985-2005

Source: PATSTAT database, authors' own calculation.
Notes: 1. Right hand side Y axis measures the number of triadic patent family, and the left hand side Y axis measures the share in triadic patent family of eight quadic patent families.
2. Triadic patents refer to the patent families which consist of patents applied for in Europe, Japan and the US. Quadic patents represent patent families which consist of patents applied for in Europe, Japan, the US and a fourth country such as Australia, Brazil, Canada, China, India, Russia, South Arica or South Korea, respectively.

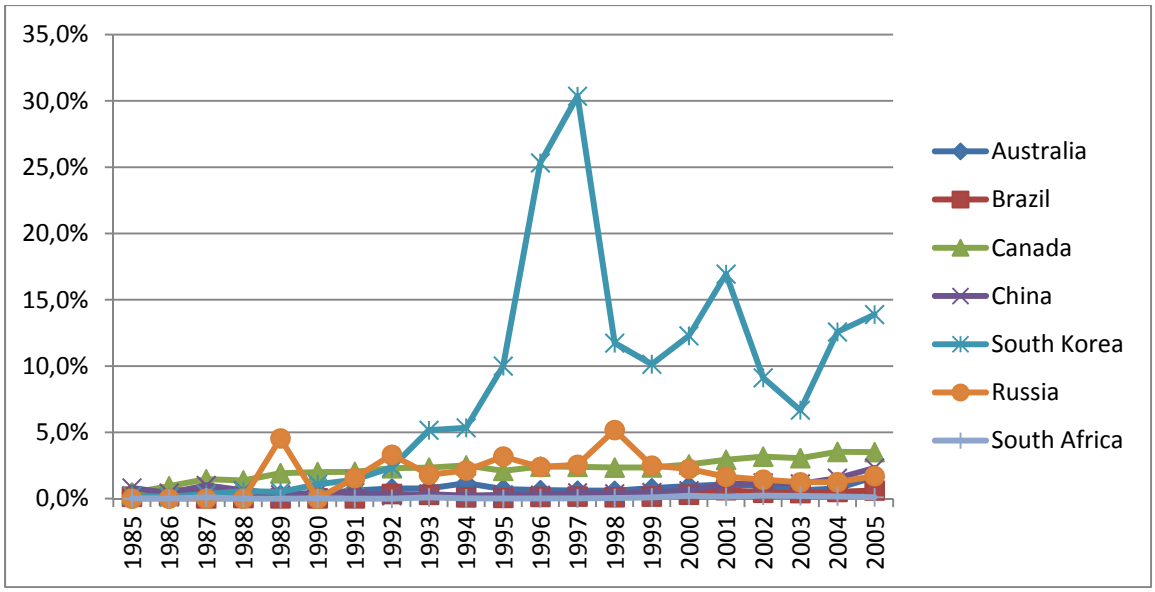

Figure 2: Proportion of the Inventors Who Reside in the Respective Country of Total Inventors of Quadic Patents

Note: We do not report India in this figure because of wide fluctuation of the value for India. From 1985 to 1998 the value for India was zero but it jumped to nearly 100 per cent in 2003. The reason is that India had a very modest number of quadic patents, hovering around 50 in the period of 2000–2005. Among this small group of inventors, majority of them resided in India. This is not uncommon for some countries in our sample which has very small number of quadic patents.

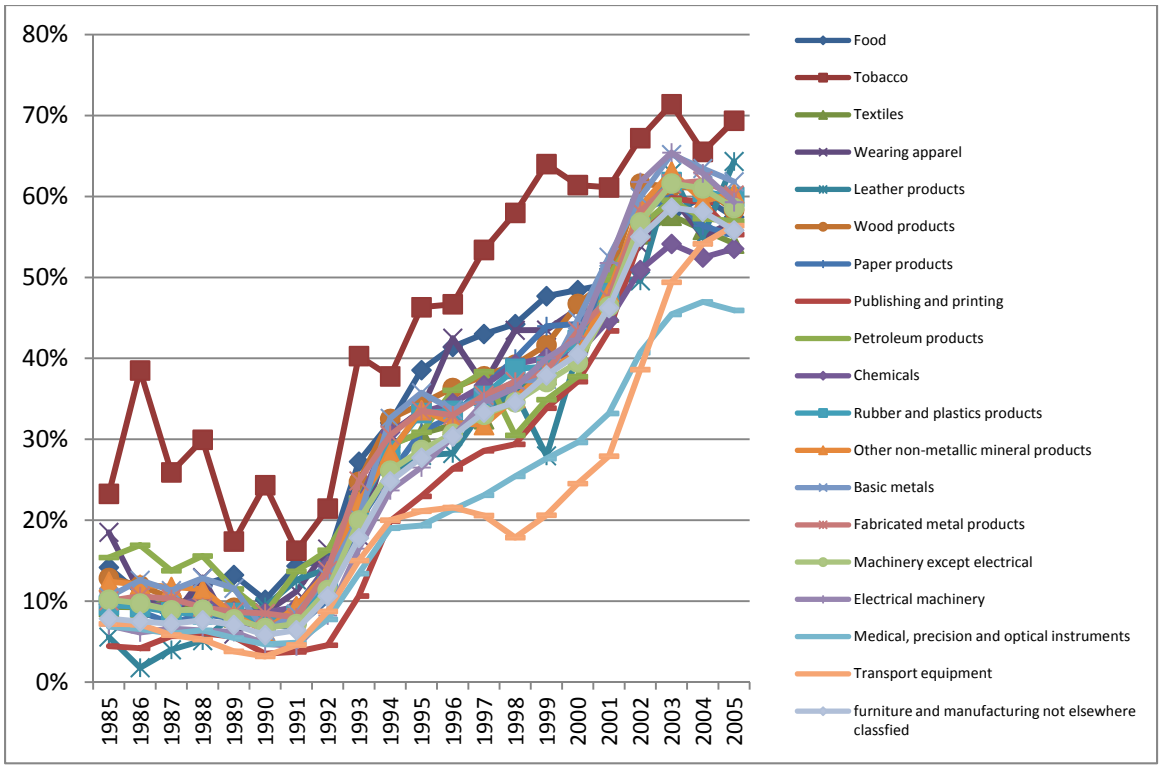

Figure 3: Proportion of the Quadic Patents of Two-Digit Manufacturing Industries in China to Triadic Patents of the Same Industries

Source: PATSTAT database, authors' own calculation.

Appendix

Table A: Harmonization of Manufacturing Sector Classification of ISIC Rev.2, ISIC Rev. 3 and Chinese Industry Sector Classification GB/T 4754-2002

Sector in this paper	ISIC Rev. 2 Three-digit sector code	ISIC Rev. 3 Two-digit sector code	Chinese GB/T 4754-2002 Two-digit sector code
Food products and beverages	311,312,313	15	13, 14, 15
tobacco products	314	16	16
textiles	321	17	17
wearing apparel	322	18	18
Leather products	323, 324	19	19
Wood products	331	20	20
Paper products	341	21	22
Publishing and printing	342	22	23
Petroleum products	353,354	23	25
Chemicals	351,352	24	26, 27, 28
Rubber and plastics products	355,356	25	29, 30
Other non-metallic mineral products	361,362,369	26	31
Basic metals	371,372	27	32, 33
Fabricated metal products	381	28	34
Machinery except electrical	382	29, 30	35, 36
Electrical machinery	383	31, 32	40, 41
Medical, precision and optical instruments	385	33	42
Transport equipment	384	34, 35	37
Furniture and manufacturing not elsewhere classified	332,390	36	21, 24, 43

Table B: Determinants of Quadic Patent Family: China Regression (Rejected Random-Effects Model)

Independent variables	Dependent variable: Quadic patents				
	1987–2004	1993–2004	1999–2004	1999–2004	1999–2004
	Random-effects	Random-effects	Random-effects	Random-effects	Random-effects
	(1)	(2)	(3)	(4)	(5)
Total sales revenue	.20***	-	.039**	-	-
	(.038)		(.019)		
Imports	-	-	-	.030*	-
				(.016)	
Sales revenue of foreign-owned firms	-	.068***	-	-	.036**
		(.026)			(.018)
Triadic patents originating in China	.14***	.16***	.15***	.15***	.16***
	(.021)	(.028)	(.038)	(.039)	(.038)
Herfindahl index	-	-	-.049***	-.054***	-.049***
			(.016)	(.017)	(.017)
Share of inventors who reside in China	-.045***	-.014	-.021	-.019	-.028
	(.013)	(.016)	(.027)	(.027)	(.027)
Triadic patents	.80***	.81***	.83***	.82***	.82***
	(.031)	(.025)	(.034)	(.035)	(.035)
Constant	-3.4***	-1.8	-1.7***	-1.9***	-1.7***
	(.25)	(.21)	(.30)	(.35)	(.30)
Year dummy	Included	Included	Included	Included	Included
Number of observations	342	228	114	114	114
Number of group	19	19	19	19	19
Log Likelihood	-1473.4	-1075.9	-565.3	-565.7	-565.6

Note: The data between the parentheses are standard deviations. *** denotes significance at the 1% level, ** denotes significance at the 5% level, * denotes significance at the 10% level.

The UNU-MERIT WORKING Paper Series

2012-01 *Maastricht reflections on innovation* by Luc Soete
2012-02 *A methodological survey of dynamic microsimulation models* by Jinjing Li and Cathal O'Donoghue
2012-03 *Evaluating binary alignment methods in microsimulation models* by Jinjing Li and Cathal O'Donoghue
2012-04 *Estimates of the value of patent rights in China* by Can Huang
2012-05 *The impact of malnutrition and post traumatic stress disorder on the performance of working memory in children* by Elise de Neubourg and Chris de Neubourg
2012-06 *Cross-national trends in permanent earnings inequality and earnings instability in Europe 1994*-2001 by Denisa Maria Sologon and Cathal O'Donoghue
2012-07 *Foreign aid transaction costs* by Frieda Vandeninden
2012-08 *A simulation of social pensions in Europe* by Frieda Vandeninden
2012-09 *The informal ICT sector and innovation processes in Senegal* by Almamy Konté and Mariama Ndong
2012-10 *The monkey on your back?! Hierarchical positions and their influence on participants' behaviour within communities of learning* by Martin Rehm, Wim Gijselaers and Mien Segers
2012-11 *Do Ak models really lack transitional dynamics?* by Yoseph Yilma Getachew
2012-12 *The co-evolution of organizational performance and emotional contagion* by R. Cowan, N. Jonard, and R.Weehuizen
2012-13 *"Surfeiting, the appetite may sicken": Entrepreneurship and the happiness of nations* by Wim Naudé, José Ernesto Amorós and Oscar Cristi
2012-14 *Social interactions and complex networks* by Daniel C. Opolot
2012-15 *New firm creation and failure: A matching approach* by Thomas Gries, Stefan Jungblut and Wim Naudé
2012-16 *Gains from child-centred Early Childhood Education: Evidence from a Dutch pilot programme* by Robert Bauchmüller
2012-17 *Highly skilled temporary return, technological change and Innovation: The Case of the TRQN Project in Afghanistan* by Melissa Siegel and Katie Kuschminder
2012-18 *New Technologies in remittances sending: Opportunities for mobile remittances in Africa* Melissa Siegel and Sonja Fransen
2012-19 *Implementation of cross-country migration surveys in conflict-affected settings: Lessons from the IS Academy survey in Burundi and Ethiopia* by Sonja Fransen, Katie Kuschminder and Melissa Siegel
2012-20 *International entrepreneurship and technological capabilities in the Middle East and North Africa* by Juliane Brach and Wim Naudé
2012-21 *Entrepreneurship, stages of development, and industrialization* by Zoltan J. Ács and Wim Naudé
2012-22 *Innovation strategies and employment in Latin American firms* by Gustavo Crespi and Pluvia Zuniga
2012-23 *An exploration of agricultural grassroots innovation in South Africa and implications for innovation indicator development* by Brigid Letty, Zanele Shezi and Maxwell Mudhara
2012-24 *Employment effect of innovation: microdata evidence from Bangladesh and Pakistan* by Abdul Waheed

2012-25 *Open innovation, contracts, and intellectual property rights: an exploratory empirical study* by John Hagedoorn and Ann-Kristin Ridder
2012-26 *Remittances provide resilience against disasters in Africa* by Wim Naudé and Henri Bezuidenhout
2012-27 *Entrepreneurship and economic development: Theory, evidence and policy* by Wim Naudé
2012-28 *Whom to target - an obvious choice?* by Esther Schüring and Franziska Gassmann
2012-29 *Sunk costs, extensive R&D subsidies and permanent inducement effects* by Pere Arqué-Castells and Pierre Mohnen
2012-30 *Assessing contingent liabilities in public-private partnerships (PPPs)* by Emmanouil Sfakianakis and Mindel van de Laar
2012-31 *Informal knowledge exchanges under complex social relations: A network study of handloom clusters in Kerala, India* by Robin Cowan and Anant Kamath
2012-32 *Proximate, intermediate and ultimate causality: Theories and experiences of growth and development* by Adam Szirmai
2012-33 *Institutions and long-run growth performance: An analytic literature review of the institutional determinants of economic growth* by Richard Bluhm and Adam Szirmai
2012-34 *Techniques for dealing with reverse causality between institutions and economic performance* by Luciana Cingolani and Denis de Crombrugghe
2012-35 *Preliminary conclusions on institutions and economic performance* by Denis de Crombrugghe and Kristine Farla
2012-36 *Stylized facts of governance, institutions and economic development. Exploring the institutional profiles database* by Bart Verspagen
2012-37 *Exploring the Panel Components of the Institutional Profiles Database (IPD)* by Luciana Cingolani and Denis de Crombrugghe
2012-38 *Institutions and credit* by Kristine Farla
2012-39 *Industrial policy for growth* by Kristine Farla
2012-40 *Explaining the dynamics of stagnation: An empirical examination of the North, Wallis and Weingast approach* by Richard Bluhm, Denis de Crombrugghe and Adam Szirmai
2012-41 *The importance of manufacturing in economic development: Past, present and future perspectives* by Wim Naudé and Adam Szirmai
2012-42 *Lords of Uhuru: the political economy of elite competition and institutional change in post-independence Kenya* by Biniam Bedasso
2012-43 *Employment and wages of people living with HIV/AIDS* by Pilar García-Gómez, José M. Labeaga and Juan Oliva
2012-44 *Prescriptions for network strategy: Does evidence of network effects in cross-section support them?* by Joel A.C. Baum, Robin Cowan and Nicolas Jonard
2012-45 *Perspectives on human development theory in democracy promotion: A comparison of democracy promotion programmes in Egypt through the lenses of classical and revised modernisation theory* by Inger Karin Moen Dyrnes
2012-46 *Nonlinearities in productivity growth: A semi-parametric panel analysis* by Théophile T. Azomahou, Bity Diene and Mbaye Diene
2012-47 *Optimal health investment with separable and non-separable preferences* by Théophile T. Azomahou, Bity Diene, Mbaye Diene and Luc Soete
2012-48 *Income polarization and innovation: Evidence from African economies* by Théophile T. Azomahou and Mbaye Dien

2012-49 *Technological capabilities and cost efficiency as antecedents of foreign market entry* by Fabrizio Cesaroni, Marco S. Giarratana and Ester Martínez-Ros

2012-50 *Does the internet generate economic growth, international trade, or both?* by Huub Meijers

2012-51 *Process innovation objectives and management complementarities: patterns, drivers, co-adoption and performance effects* by Jose-Luis Hervas-Oliver, Francisca Sempere-Ripoll and Carles Boronat-Moll

2012-52 *A systemic perspective in understanding the successful emergence of non-traditional exports: two cases from Africa and Latin America* by Michiko Iizuka and Mulu Gebreeyesus

2012-53 *Determinants of quadic patenting: Market access, imitative threat, competition and strength of intellectual property rights* Can Huang and Jojo Jacob